SUSY Benchmarking Analyses with SiD

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Outline

- Chargino/neutralino masses
  - Signal selection
  - Kinematic fitting
  - Mass measurement
- Cosmology motivated sbottom production
  - B-tagging
  - Results

Introduction

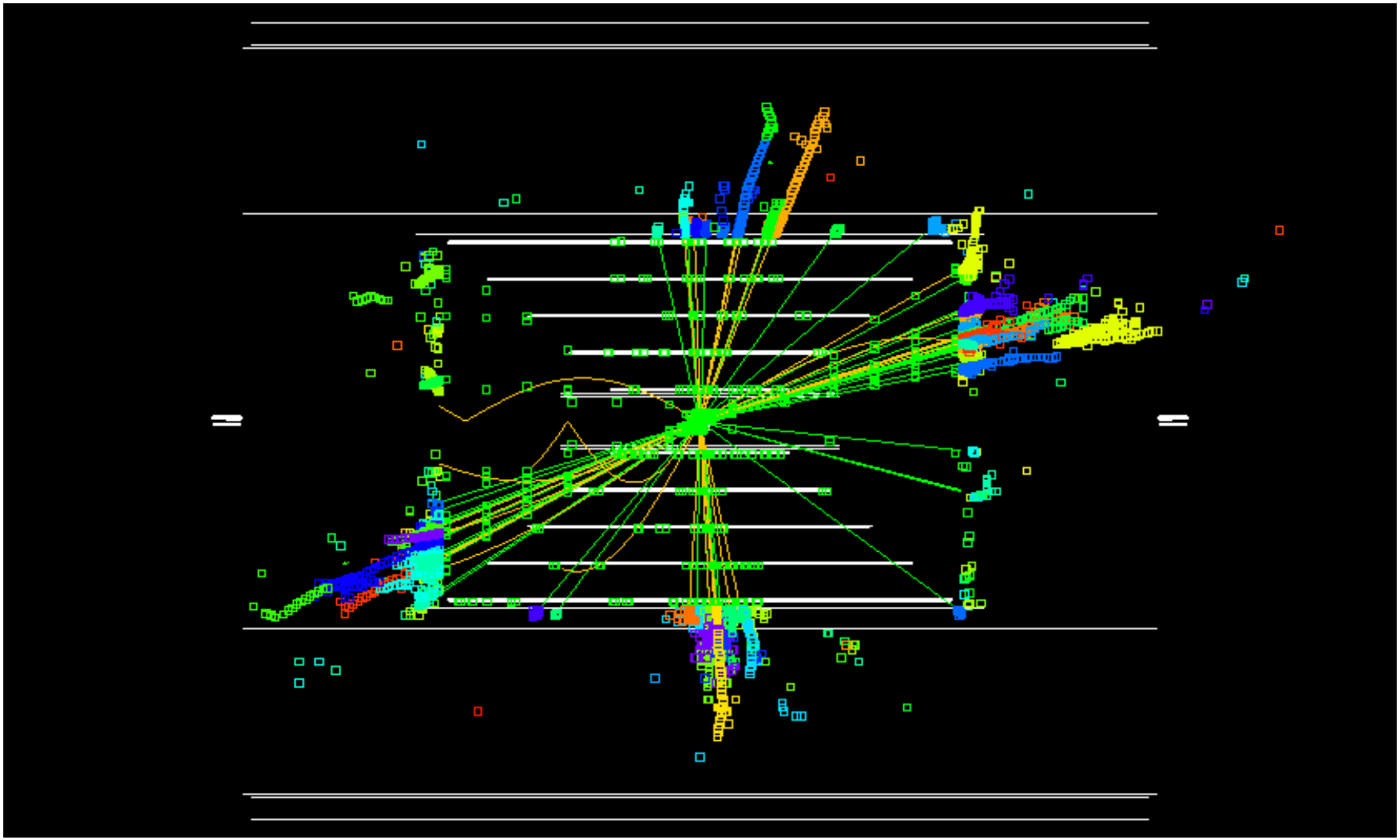
- Physics process: (SUSY point 5 in ILC benchmarks)

$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 q\bar{q}q\bar{q}$$
$$e^+e^- \rightarrow \tilde{\chi}_2^0\,\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 Z^0Z^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 q\bar{q}q\bar{q}$$

parameter	value
m_0	206 GeV
$m_{1/2}$	293 GeV
$\tan\beta$	10
A	0
μ	375 GeV
$M_{\tilde{\chi}_1^0}$	115.7 GeV
$M_{\tilde{\chi}_1^\pm}$	216.5 GeV
$M_{\tilde{\chi}_2^0}$	216.7 GeV

  - $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$ dominantly decay into on-shell W/Z
  - Cross-section not too small
    - $\tilde{\chi}_1^+\tilde{\chi}_1^-$ ~ 100 fb
    - $\tilde{\chi}_2^0\,\tilde{\chi}_2^0$ ~ 10 fb
  - The gauge boson energy depends on the parent and LSP mass
- Signature: 4 jets (from 2 acoplanar W/Z) + missing energy
  - WW/ZZ separation: good PFA performance required

e+e- -> ne2ne2 -> ne1ne1ssdd



Samples

- SUSY samples:
  - $\sqrt{s}$ = 500 GeV; 500 fb^{-1} luminosity; ~ 1.2M events /sample
  - Polarization: 80% e- L, 30% e+ R
  - SUSY Backgrounds: e+e- -> ne1ne2, slepton pair production

sample	$m_{\tilde{\chi}_1^0}$ (GeV)	$m_{\tilde{\chi}_1^\pm}$ (GeV)	$m_{\tilde{\chi}_2^0}$ (GeV)
Template	115.7	216.7	216.5
neu1 + 0.5	117.2	216.7	216.5
ch + 0.5	115.7	217.2	216.5
ch + 0.5	115.7	216.7	217.0

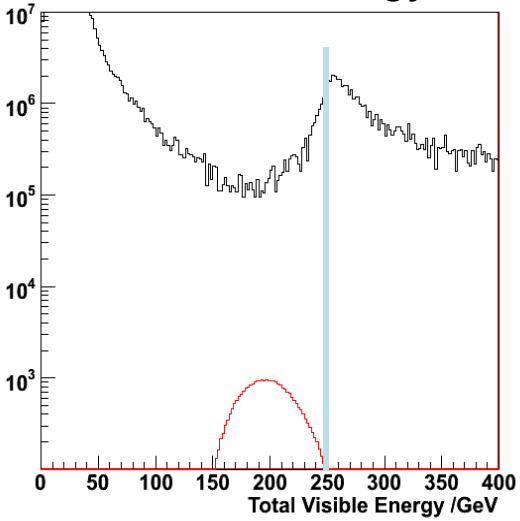
Signal selection

cut	value
E_{jet}	> 10 GeV
Fraction of EM energy in each jet	$< 80\%$
Number of tracks	> 20
Total visible energy	< 250 GeV
Thrust	< 0.85
$\cos\theta_{thrust}$	< 0.9
$\theta(1, 2)$	$> 60°$
$\theta(1, 3)$, $\theta(1, 4)$, $\theta(1, 3)$	$> 40°$
$\theta(2, 4)$, $\theta(3, 4)$	$> 20°$
Acoplanarity of two reconstructed gauge bosons	$> 10°$

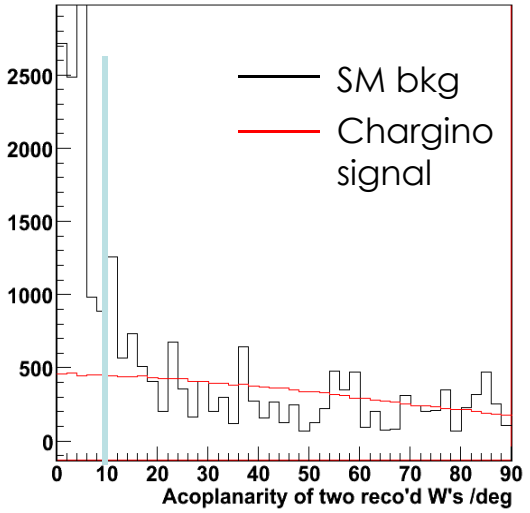
Before Chargino/Neutralino separation:

	Chargino all-hadronic signal	Neutralino all-hadronic signal	SM background
Efficiency	60.1%	59.3%	0.0004%
Composition	36.7%	6.9%	53.5%

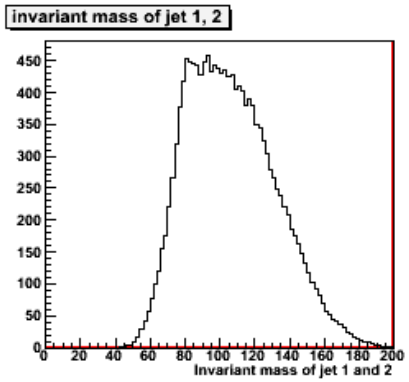
Total visible energy

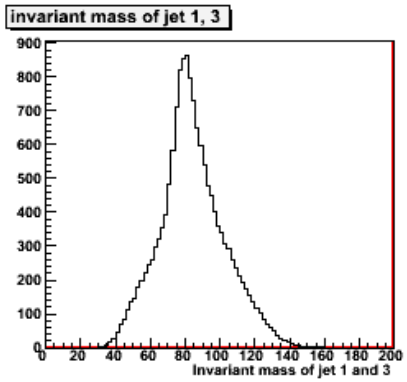


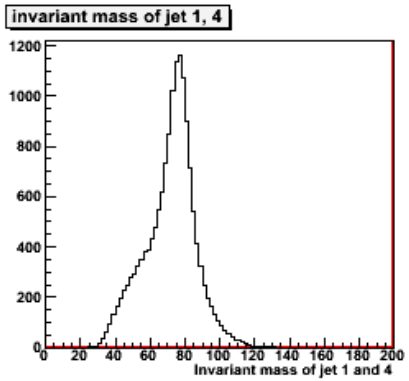
Acoplanarity btw 2 W's

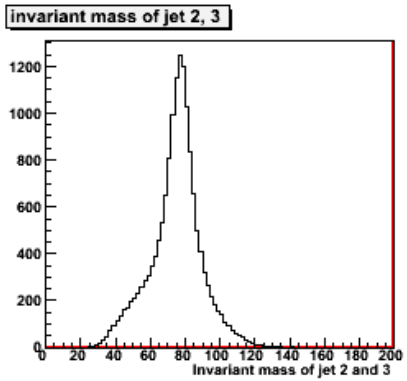


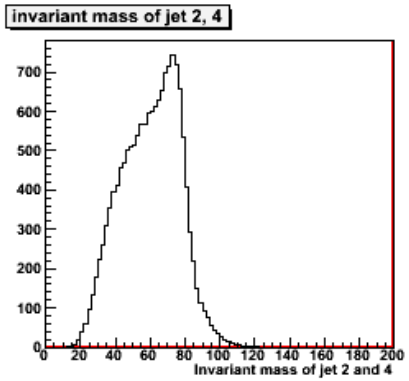
W/Z Reconstruction – Jet pairing

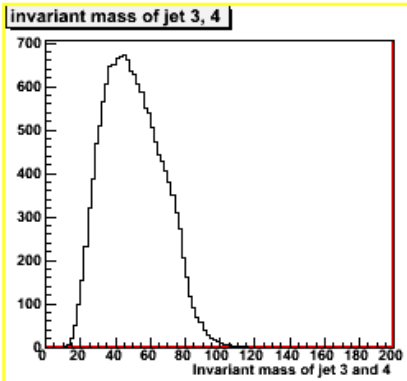










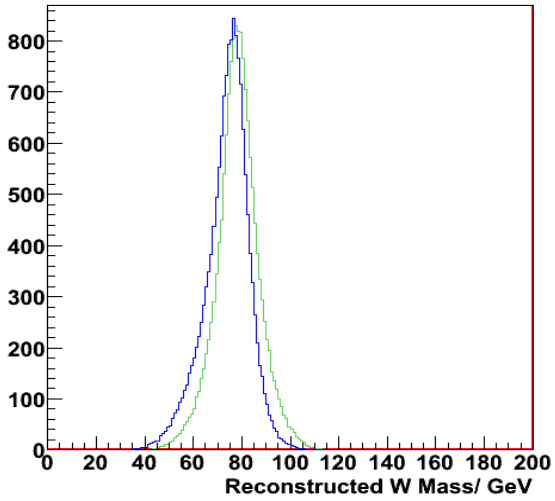


- Chargino/Neutralino signal separation is based on the two reconstructed boson mass: W or Z
- Need to pair jets correctly
- Jet pairing optimization: Choose the combination minimizing:

$$(m_{i,k} - m_W)^2 + (m_{l,n} - m_W)^2$$

Green: Reco'd mass of 1st W

Blue: Reco'd mass of 2nd W



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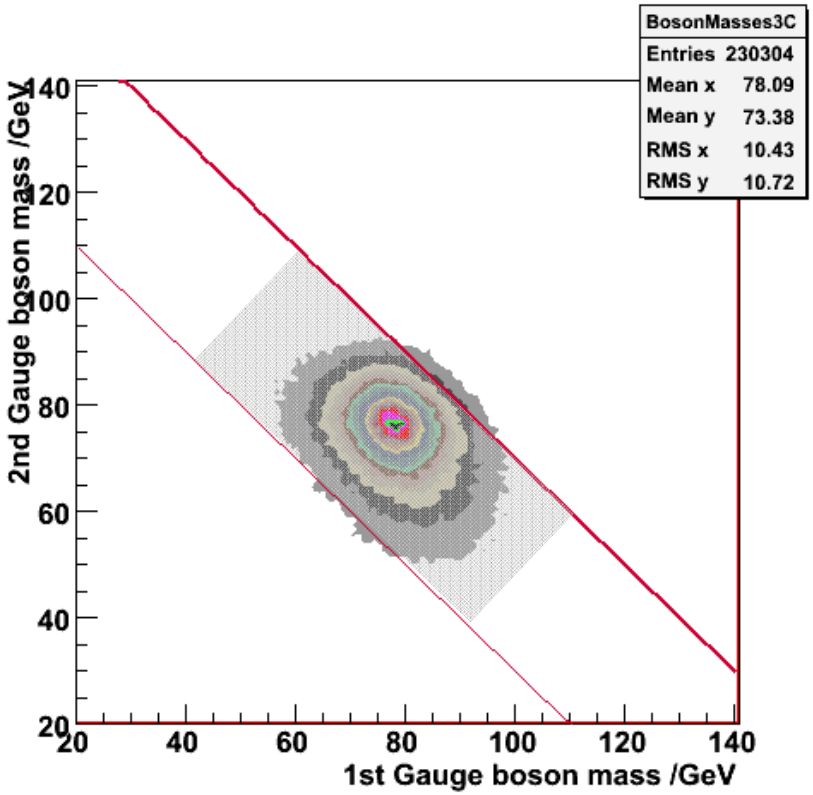
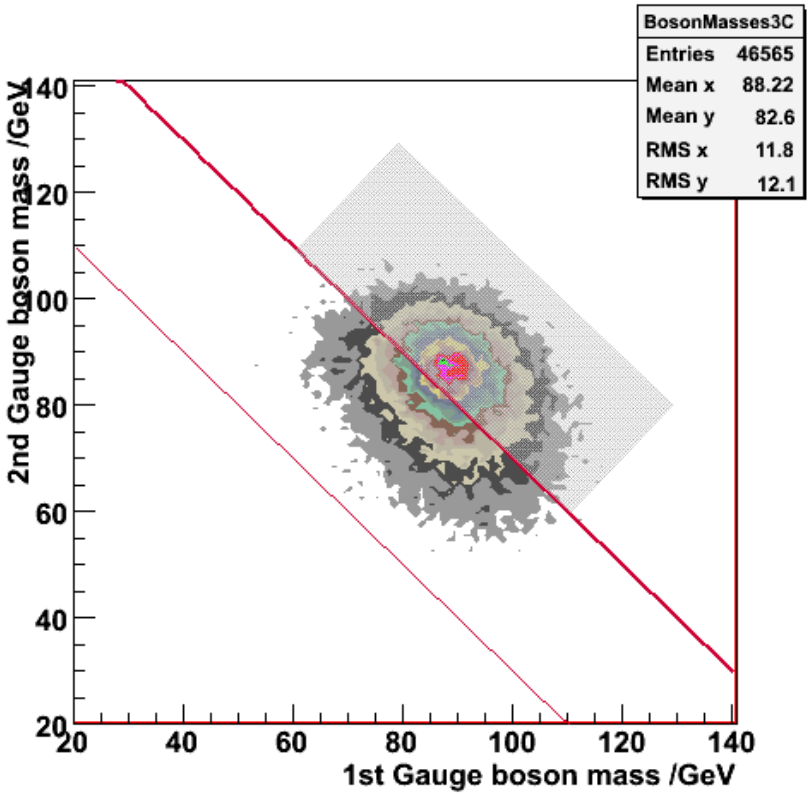
Chargino/ Neutralino Separation

Correlation of two di-jet masses is a powerful selection criteria





Chargino events signal

130 GeV < M(W1) + M (W2) < 172 GeV

Neutralino events signal

M(W1) + M (W2) > 172 GeV

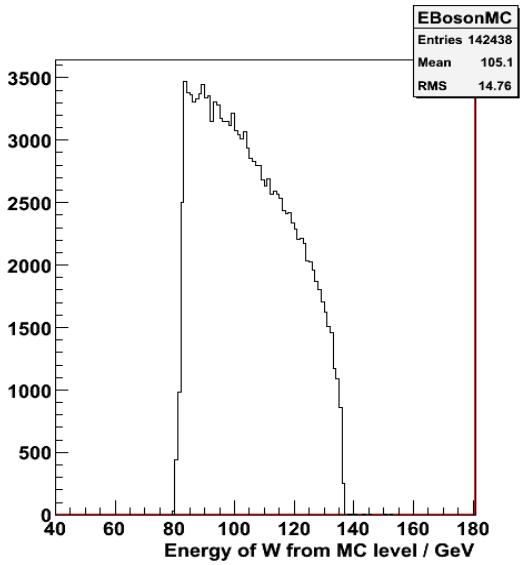
Chargino/Neutralino mass – strategy

- When C1(N2) -> N1 + W(Z), in C1 rest frame, the W is monochromatic

$$E_W = \frac{|(m_{chi}^2 + m_W^2 - m_{neu}^2)|}{2m_{chi}}$$

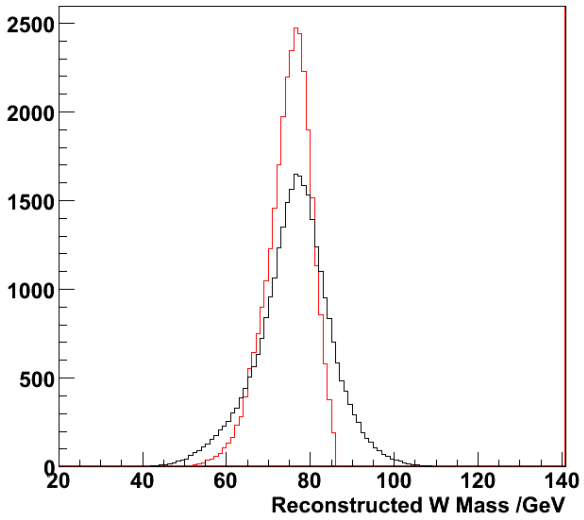
- In lab frame the W is boosted but E_W still depends on the mass of chargino and neutralino.

- We can extract the chargino/neutralino mass by comparing the W/Z energy spectrum to the template.

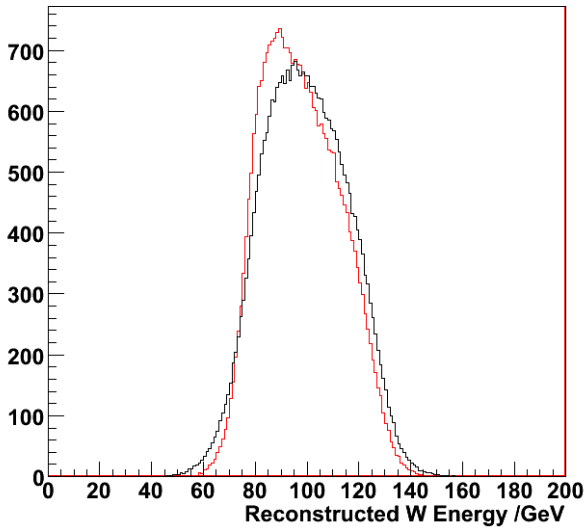


Kinematic fitting

- Kinematic fitting with one constraint (Mboson1 = Mboson2) improves the boson energy resolution
  - Used KinFit in Marlinreco package (J.List et al)
  - Jet resolutions: $\delta E = 50\%/\sqrt{E}$; $\delta\theta$, $\delta\phi$ = 0.1 rad



Reco'd W mass



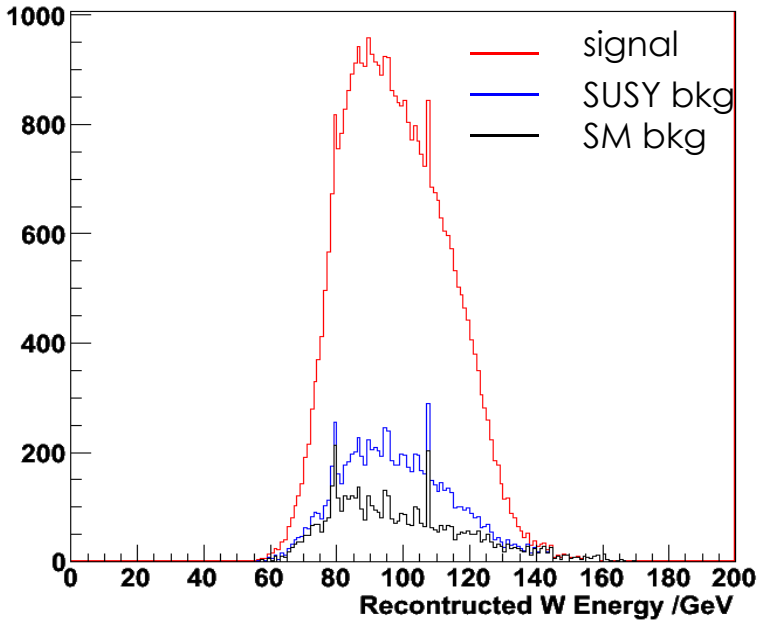
Reco'd W energy

Chargino selection:

Before/ After Kinfit

Result – boson energy spectrum

Chargino selection:

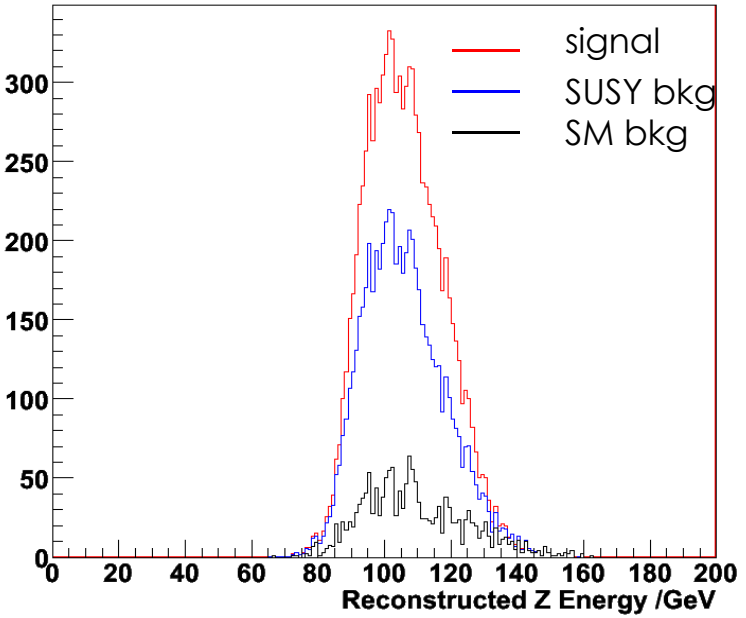


Purity : 75.3%

Efficieny : 53.8%

Xsection error: 0.9%

Neutralino selection:

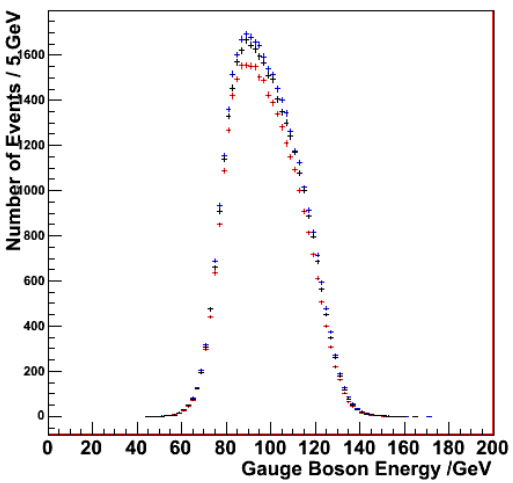


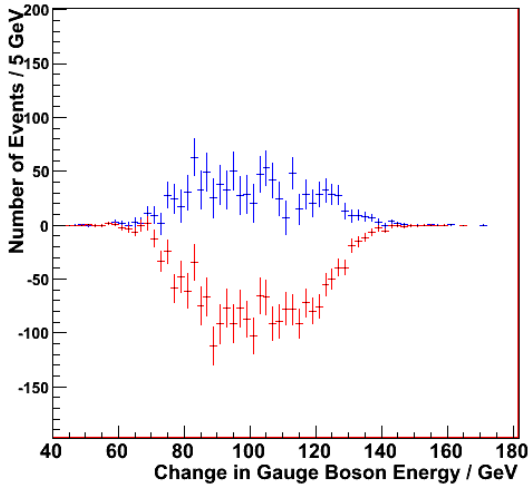
Purity : 33.7%

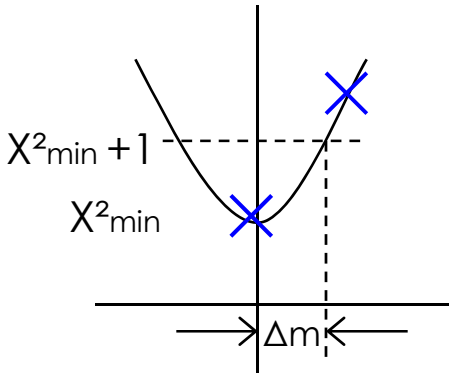
Efficieny : 30.2%

Xsection error: 4.2%

Result – mass uncertainty







Blue: chargino+0.5, red: neu1+0.5

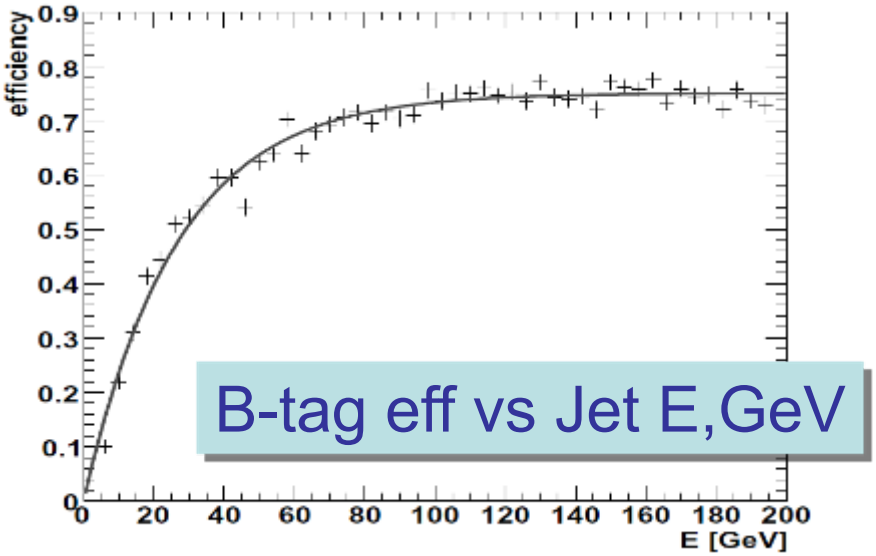
Chargino signal templates (SM bkg not included)

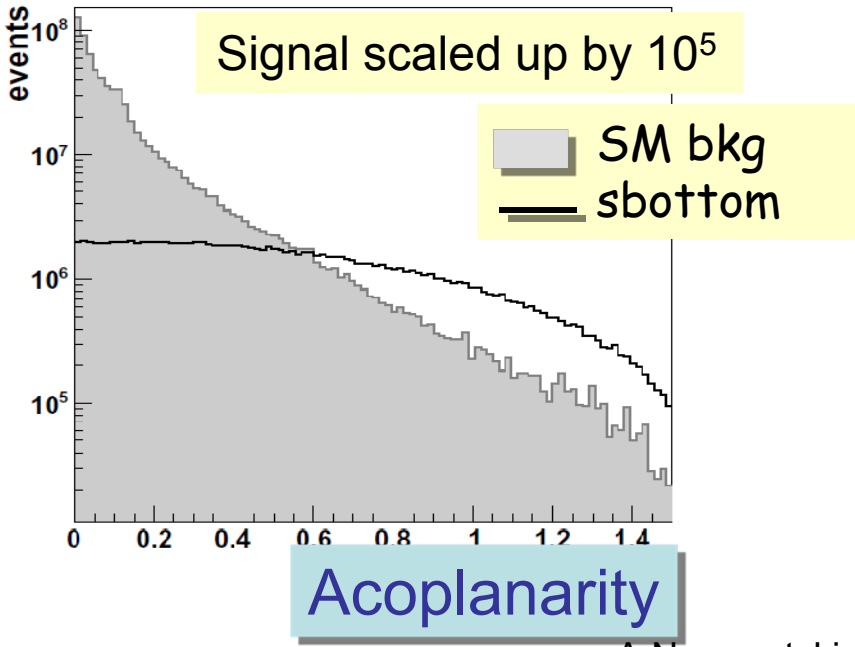
$$\chi_1^2 = \sum_{i=0}^{Nbins} \frac{(y_{template1,i} - y_{data,i} + \delta_i)^2}{\sigma^2_{template1,i} + \sigma^2_{data,i} + \sigma^2_{SM,i}}$$

Chargino selection		Neutralino selection	
Chargino	95 MeV	Neu2	369 MeV
Neu1	54 MeV	Neu1	102 MeV
		(Chargino	395 MeV)

Sbottom Production

- Cosmology motivated SUSY predicts small mass split between LSP and NLSP
  - Small visible energy in the detector
  - Assume NLSP is sbottom
  - Two b-jets + MET
  - Jet clustering and b-tagging are challenging for low energy jets
- Huge $jj\gamma\gamma$ and $jj\gamma$ backgrounds
  - Need to use forward calorimeter for rejection





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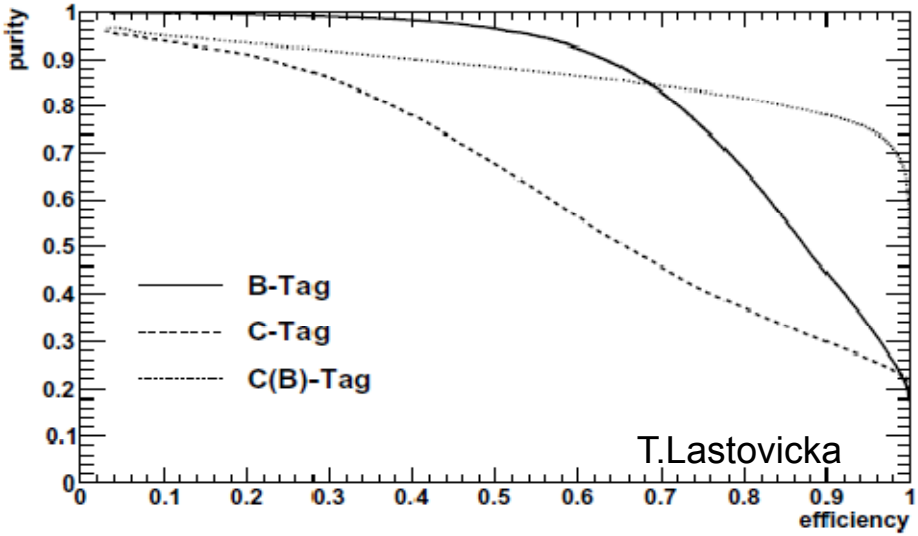
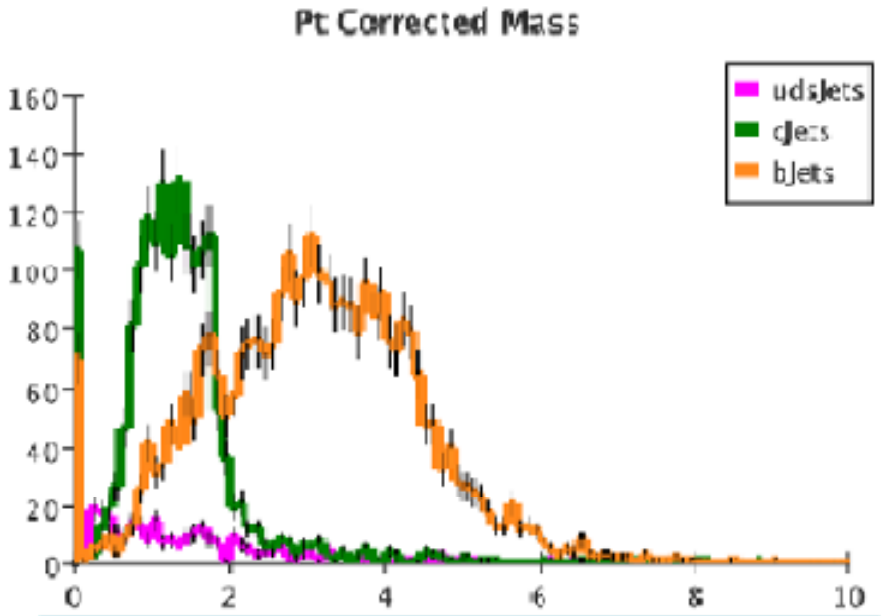
LCFI b-tagging

- Vertexing: LCFI package
  - NN based on flavour discriminants
  - Re-optimized for SiD using 500 GeV dijets
  - Re-optimized for sbottom signal
    - Deterioration at small E recovered



Purity vs Efficiency



Corrected vertex mass, GeV

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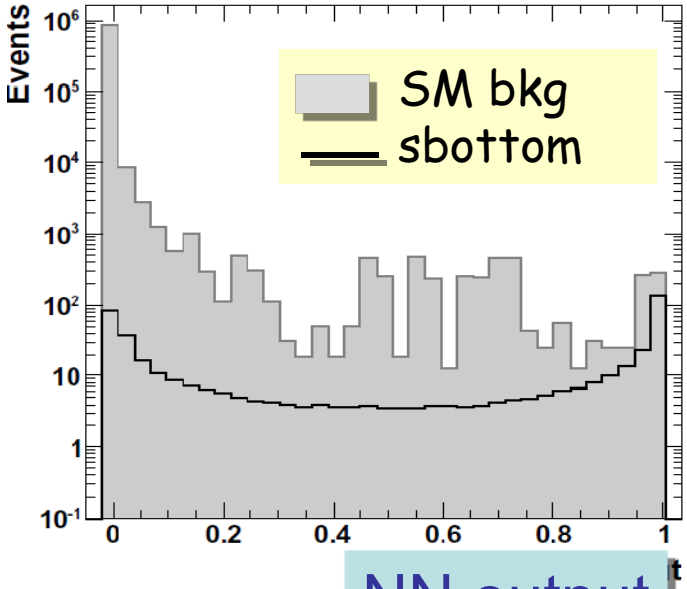
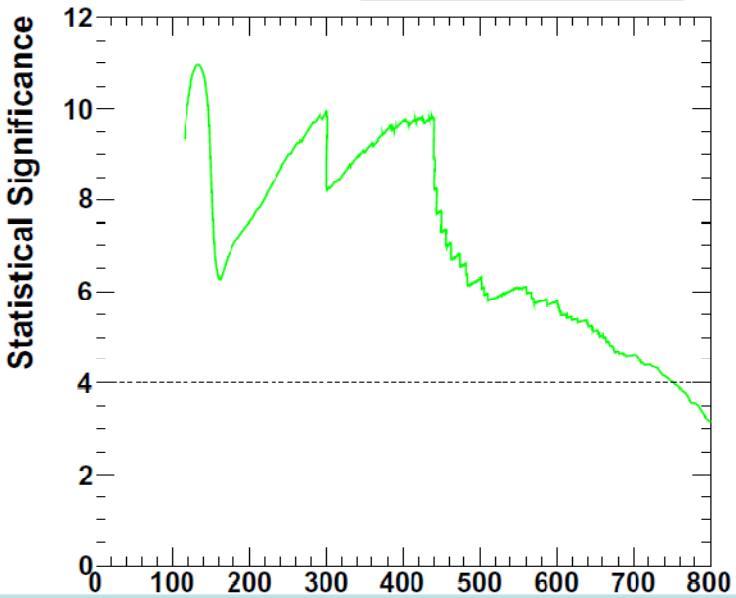
Sbottom Production

- Main selections
  - Visible energy < 80 GeV
  - Number of particle
  - Forward EM veto, acceptance 10 mrad, E > 300 MeV
- Main discriminating variables combined in NN, also adding
  - Acoplanarity
  - Maximum pseudorapidity
  - ΔR
- Results
  - 15% Cross section measurement for

$$m_{\tilde{b}} = 230\,\mathrm{GeV} \text{ and } m_{\tilde{\chi}_1^0} = 210\,\mathrm{GeV}$$

  - Sensitive to sbottom-neutralino mass difference down to 10 GeV





Significance vs # signal events

Summary

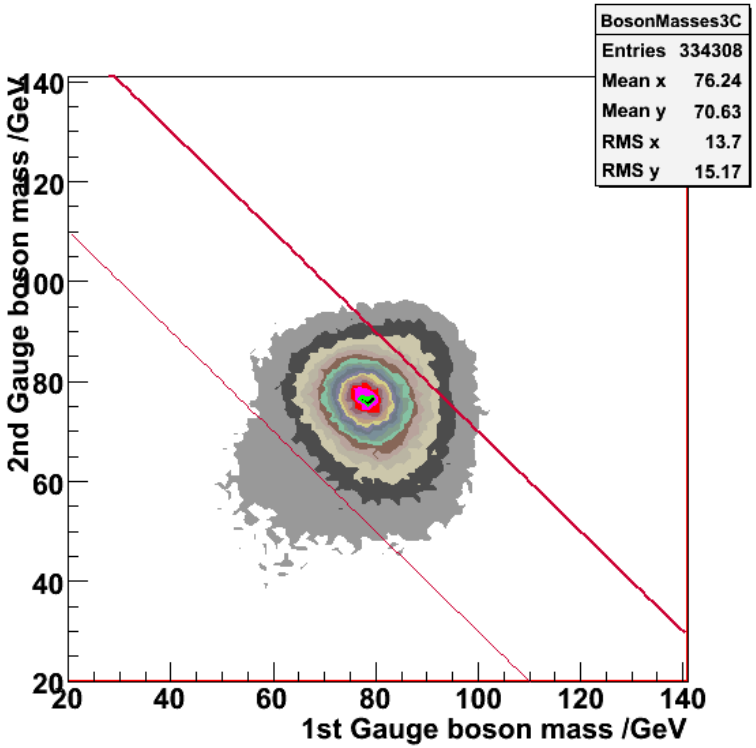
- Chargino / neutralino events can be identified and efficiently separated from each other.
- The cross section uncertainty of chargino and neutralino2 signals are 0.9% and 4.2% respectively
- Chargino1 and Neutralino2 masses can be determined with 100 MeV and 370 MeV uncertainty using the template method

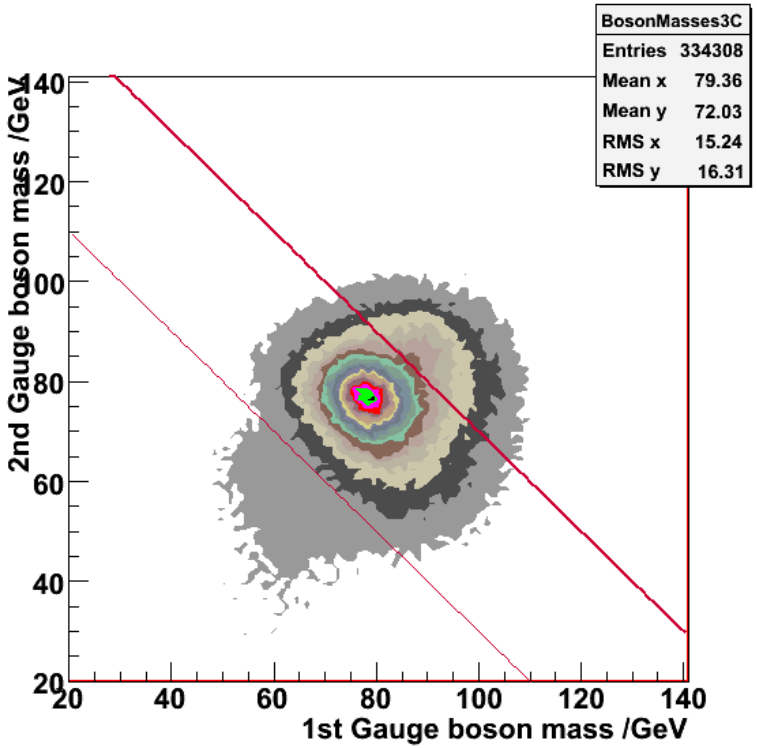
- Cosmology motivated SUSY sbottom scenarios can be constrained to the sbottom-neutralino mass difference of 10 GeV

More details and references can be found at SiD Letter of Intent:

http://silicondetector.org/display/SiD/LOI

Backups



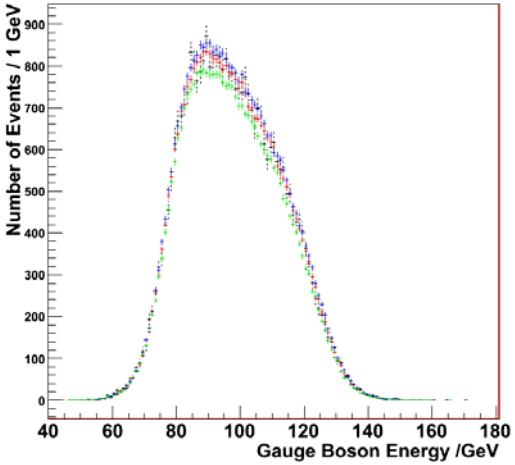


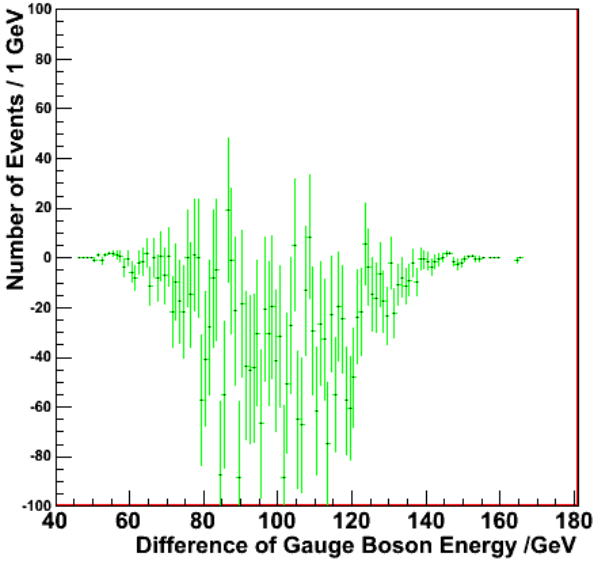
The two boson masses of all SUSY events

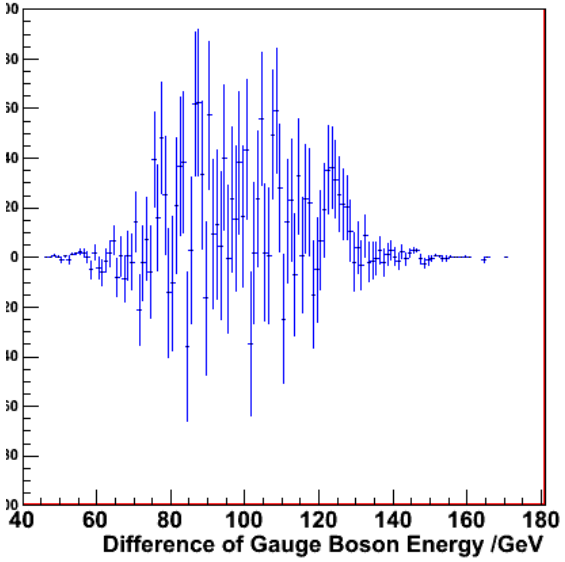
Left: chargino events selection; right: neutralino events selection

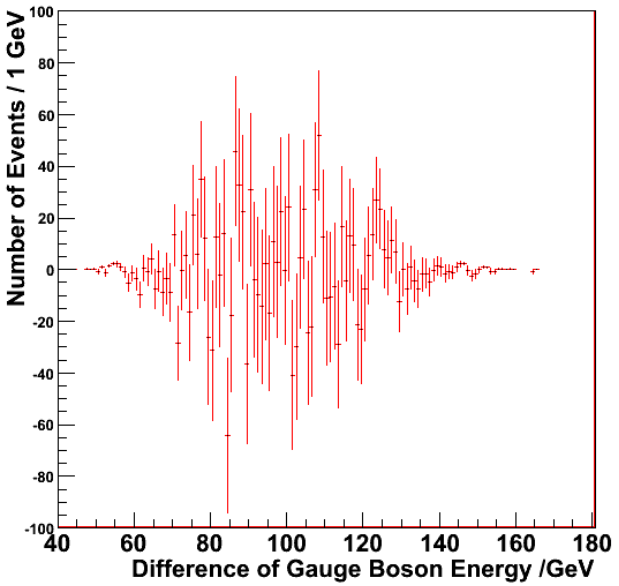
SUSY Mass Templates

- Templates have different SUSY masses
- Difference between ‘Data’ and templates









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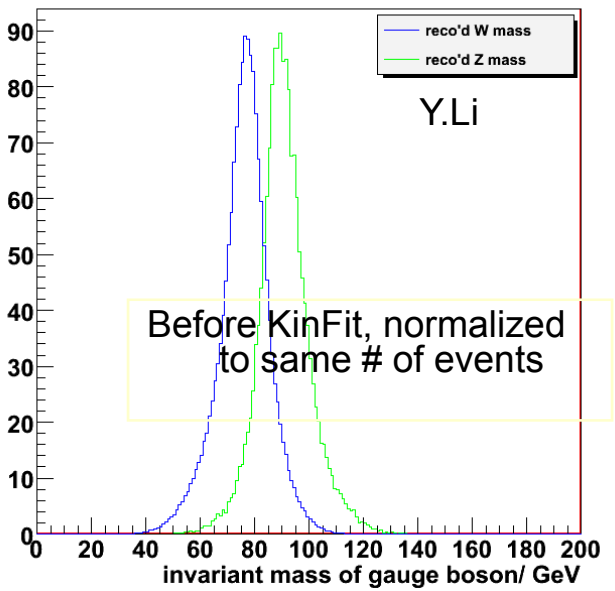
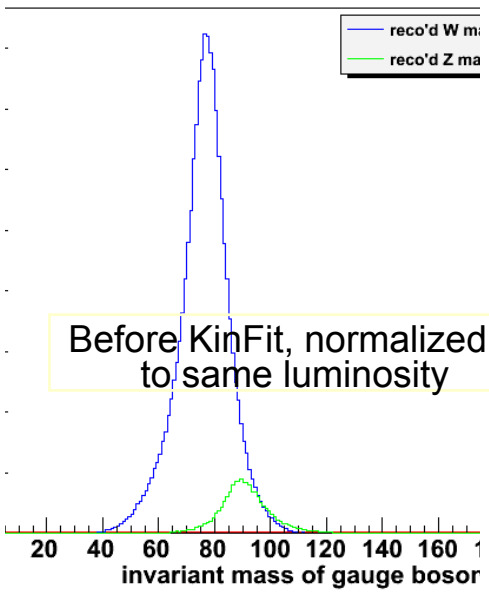
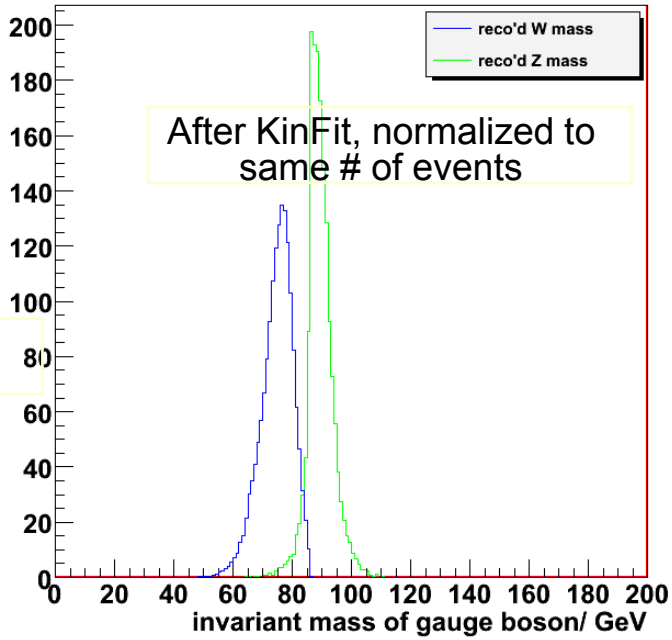
Di-jet Mass Resolution

- For SUSY analysis
  - σ~8 GeV before KinFit
  - σ~4 GeV after KinFit
- Physics analysis includes
  - Boson natural width
  - All quark species (light, c, b) – neutrinos from c, b can worsen the resolution
  - Forward CAL
  - Effects of jet clustering (FSR, jet confusion and combinatorics). Events are forced in 4 jets.

Vector boson invariant mass for chargino and neutralino2 signals







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